NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 11-85

HUMAN FACTORS EVALUATION OF THE SUPERLITE 17B HELMET IN THE SURFACE-SUPPLIED, OPEN-CIRCUIT MODE

By:

Michael D. Curley, LCDR, MSC, USN

1986

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NAVY EXPERIMENTAL DIVING UNIT
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January 1986

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A human factors engineering evaluation of the Diving Systems International Superlite 17B diving helmet was conducted by the U.S. Navy Experimental Diving Unit. In the dry, unmanned bench portion of this assessment, several design recommendations were made to improve diver safety and operation of the helmet. The Superlite 17B was then evaluated side-by-side with the U.S. Navy MK 1 Mod S Diver's Mask during a series of

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in-water dives ranging from one to four hours. Four teams of two divers wore either the Superlite 17B or MK 1 Mod S Diver's Mask while accomplishing tasks designed to test the comfort, safety, operation, maintainability, communications, and breathing resistance of both diving rigs. Results indicated that to ensure safe and comfortable operation of the Superlite 17B helmet, careful attention must be exercised in the fitting of the neck-dam, oral nasal mask, and head cushion. Additional recommendations for design modifications of the Superlite 17B were made. Overall, the Superlite 17B was found to be adequate in its human factors engineering design.

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ABSTRACT

A human factors engineering evaluation of the Diving Systems International Superlite 17B diving helmet was conducted by the U.S. Navy Experimental Diving Unit. In the dry, unmanned bench portion of this assessment, several design recommendations were made to improve diver safety and operation of the helmet. The Superlite 17B was then evaluated side-by-side with the U.S. Navy MK 1 Mod S Diver's Mask during a series of in-water dives ranging from one to four hours. Four teams of two divers wore either the Superlite 17B or MK 1 Mod S Diver's Mask while accomplishing tasks designed to test the comfort, safety, operation, maintainability, communications, and breathing resistance of both diving rigs. Results indicated that to ensure safe and comfortable operation of the Superlite 17B helmet, careful attention must be exercised in the fitting of the neck-dam, oral nasal mask, and head cushion. Additional recommendations for design modifications of the Superlite 17B were made. Overall, the Superlite 17B was found to be adequate in its human factors engineering design.

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INTRODUCTION

The U.S. Navy evaluated previously the Diving Systems International (DSI) Superlite 17B helmet for specific diving applications. Unmanned testing of the Superlite 17B helmet by the Navy Experimental Diving Unit (NEDU) in 1979 assessed breathing resistance, sideblock pressure drop, and breathing work in accordance with military specifications. The helmet met or exceeded all military requirements in these areas [reference (1)]. Further testing of the helmet was conducted by NEDU in the spring of 1984. The Superlite 17B was evaluated as to its physiological suitability as a deep-sea helmet for use in a Personnel Transfer Capsule (PTC). A side-by-side comparison of the helmet was conducted with the U.S. Navy's MK 1 Mod S diver's mask during DEEP DIVE 84, a helium-oxygen saturation dive to a simulated depth of 850 feet of sea water (FSW). That particular test was designed to (1) assess the capability of the Superlite 17B to support heavy exercise at great depths and (2) delineate the breathing characteristics of this helmet at depth. In summary, the Superlite 17B was found capable of adequately supporting (physiologically) a working diver at 850 FSW [reference (2)].

However, to date the U.S. Navy has not conducted any systematic manned evaluations of the Superlite 17B as a conventional surface-supplied diving system, nor investigated the suitability of its use in a PTC application from other than a physiological viewpoint. The Defense and Civil Institute of Environmental Medicine (DCIEM) of Canada conducted a series of studies on the Superlite 17B [references (3), (4), (5)] which documented potential problem areas in using the Superlite 17B. These problem areas centered on helmet balance, oral-nasal mask sizing, and helmet liner fit.

This investigation was undertaken in conjunction with reference (6) to conduct a human factors engineering analysis of the helmet, with particular emphasis on its suitability for use during dives of long durations as may be anticipated if the helmet would be used in a saturation diving role.

BENCH EVALUATION OF SL 17B

The Superlite 17B Deep Sea Diver's Helmet is manufactured by Diving Systems International, 425 Garden Street, Santa Barbara, California 93101. It is a two piece helmet, consisting of a neck dam-yoke and a hat, designed for either mixed-gas or air diving. The "B" designation refers to the location of the side block, which receives the diver's umbilical from behind, contrasted with the "A" model which receives the umbilical from in front of the diver. In addition, the "B" model uses a metal gas supply tube to the regulator vice rubber hose on the "A" model. One Superlite 17B helmet (SL 17B) was obtained from the NEDU diving locker and brought up to its manufacturer's current specifications [reference (7); Figure 1]. This helmet was used previously in a study at 850 FSW [reference (2)] and was approximately eight years old. A second, brand new Superlite 17B helmet was procured for this test from DSI along with a new instruction manual, helmet liner, and neck dam clamp/yoke assembly (Figure 2). Both helmets used in this evaluation were "B" models, manufactured at least 7 years apart.

Physical Characteristics of Helmet

Both helmets were weighed with their neck dam-yoke and liner. The older SL 17B weighed 448.8 oz; the newer version weighed 423.6 oz. By component, the weight of the helmets were: old (helmet-348.8 oz; neck dam-yoke-78.4 oz;

FIGURE 1. OLDER SUPERLITE 17B DIVING HELMET

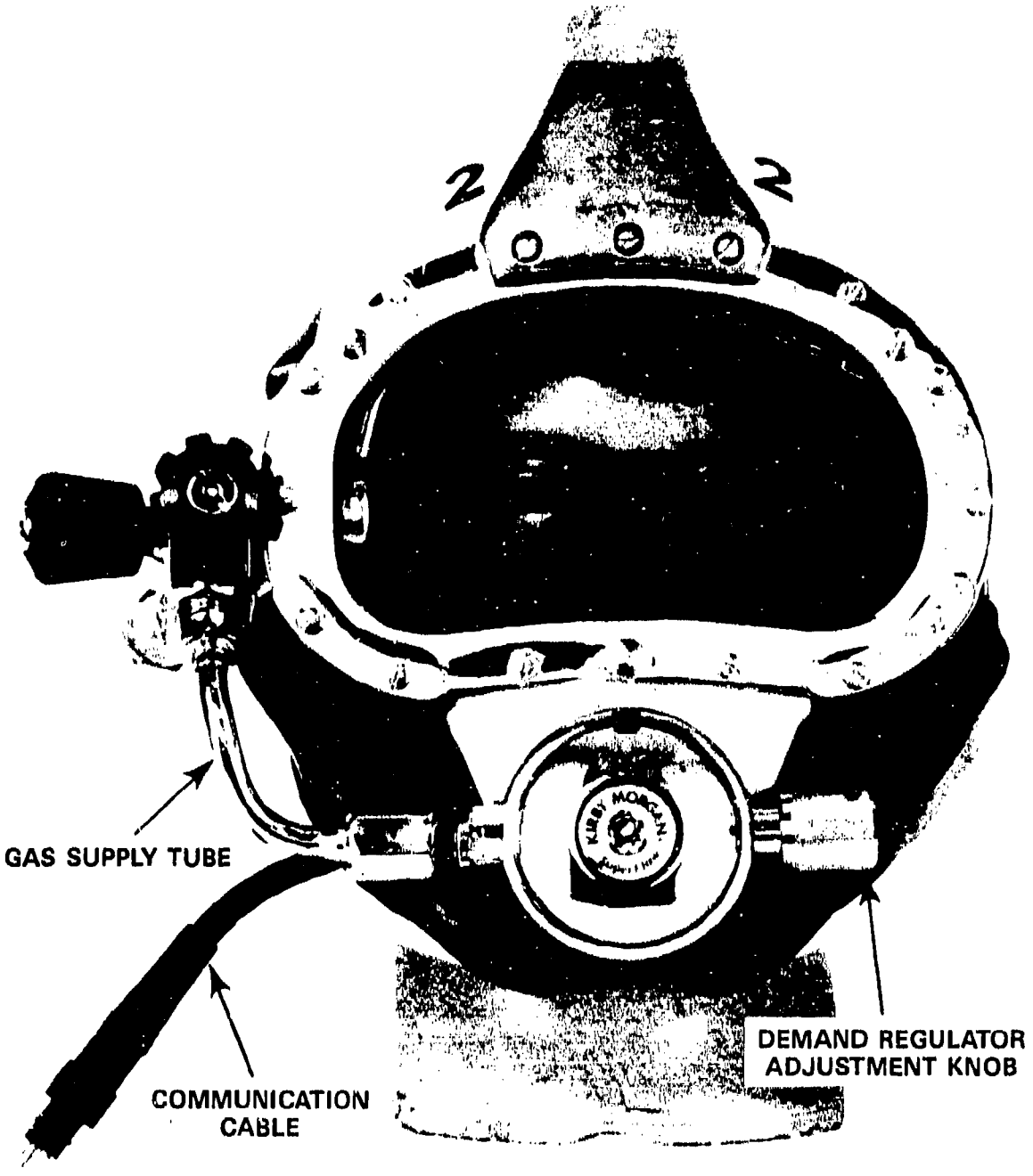

FIGURE 2. NEWER SUPERLITE 17B DIVINC HELMET

liner-11.4 oz);new (helmet-339.2 oz; neck dam-yoke-74.0 oz; liner-10.4 oz). A weight reduction of ~1.5 pounds is evident in the newer combination, with most of the reduction attributable to the helmet itself. Easily discernable differences in the helmets were few. The newer helmet displayed a flattened handle weight on top of the helmet (Figure 3), a locally drilled hole in the neck dam/yoke pin to receive a safety clasp (Figure 4), a different interior helmet hard liner (Figure 5), different ear phone clips (Figure 5), a rubber-covered nose clearing device, a differently machined exhaust port, a different seal between the hat and neck dam/yoke, and the absence of a gas supply heater shroud (Figure 2). Keeping in mind these differences, a detailed description of the newer hat follows.

Human Factors Observations

Main Gas Supply Handle: (Figure 3). This handle controls passage of gas from the umbilical into the helmet interior. (The instruction manual refers to this supply of gas as the "steady flow gas"). It is black, 12 cm in diameter with 4 knobs 4 cm in diameter, and is easy to grip even with a three-fingered neoprene glove. The valve has a positive stop in either direction, and requires 2 1/2 turns from full open to fully closed. Light effort is required to turn this valve with a gloved hand.

Emergency Gas Supply Handle: (Figure 3). This handle is of identical design to the main gas supply handle. However, the handle must be turned 5 3/4 times before completing a full open to full shut evolution. Fewer turns (2-3) from full open to fully shut would be more efficient. Light effort is required to turn this handle.

Demand Regulator Adjustment Knob: (Figure 2). This knob is brass, 2.6 cm in diameter, 2.1 cm long, and requires 16 full turns from positive stop to positive stop. Sixteen turns is considered excessive, with most divers being unable to perceive a difference in breathing resistance after 1 or 2 turns only.

Helmet Shell: The shell is one piece and molded of fiberglass and polyester resin, colored yellow for high visibility. It contains holes for mounting of its various component parts. The interior of the helmet is lined with a black patterned material (Figure 5), composition unknown. The faceplate is made of 0.6 cm thick clear LEXAN®, held in place with a brass retaining ring, and measures 19 cm by 10.5 cm. Little distortion due to the lens is evident on the surface.

Communications:(Figures 5 and 6): The 6.9 cm diameter earphones are encased in rubber and held in place securely by earphone retainer clips (DSI accessory part 540-054). The microphone is contained in the oral-nasal mask. The diver can be hatted and unhatted without the removal of the earphones and microphone, a convenience and a plus for reliability. The two communication bolt posts located on the right side of the diver's oral-nasal mask are potentially hazardous. The lower bolt can be felt through the oral-nasal mask when the helmet is displaced. A protective rubber cap should be placed onto these posts to minimize the chance of facial injury.

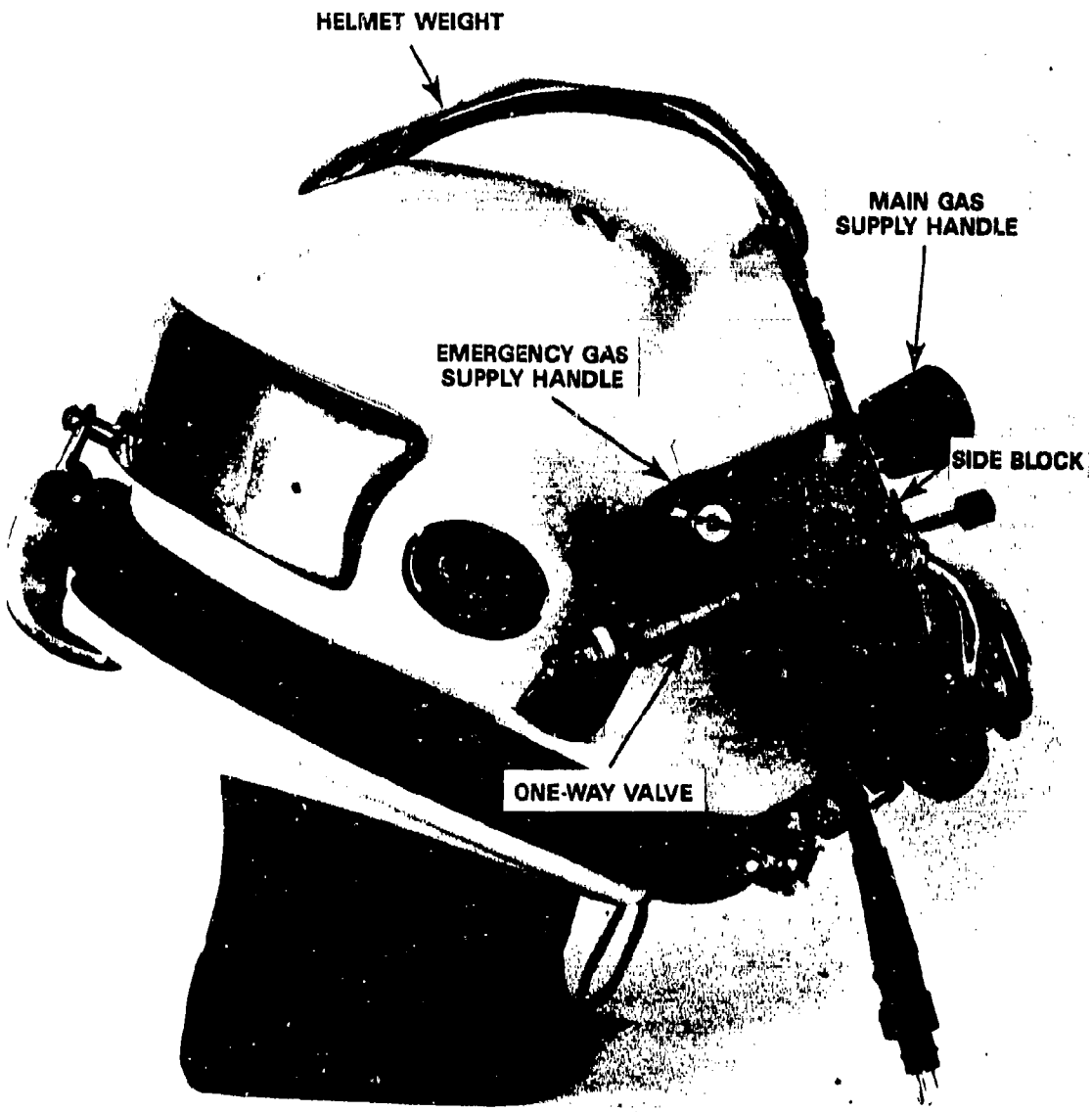

FIGURE 3. FLATTENED HANDLE WEIGHT ON SL 17B

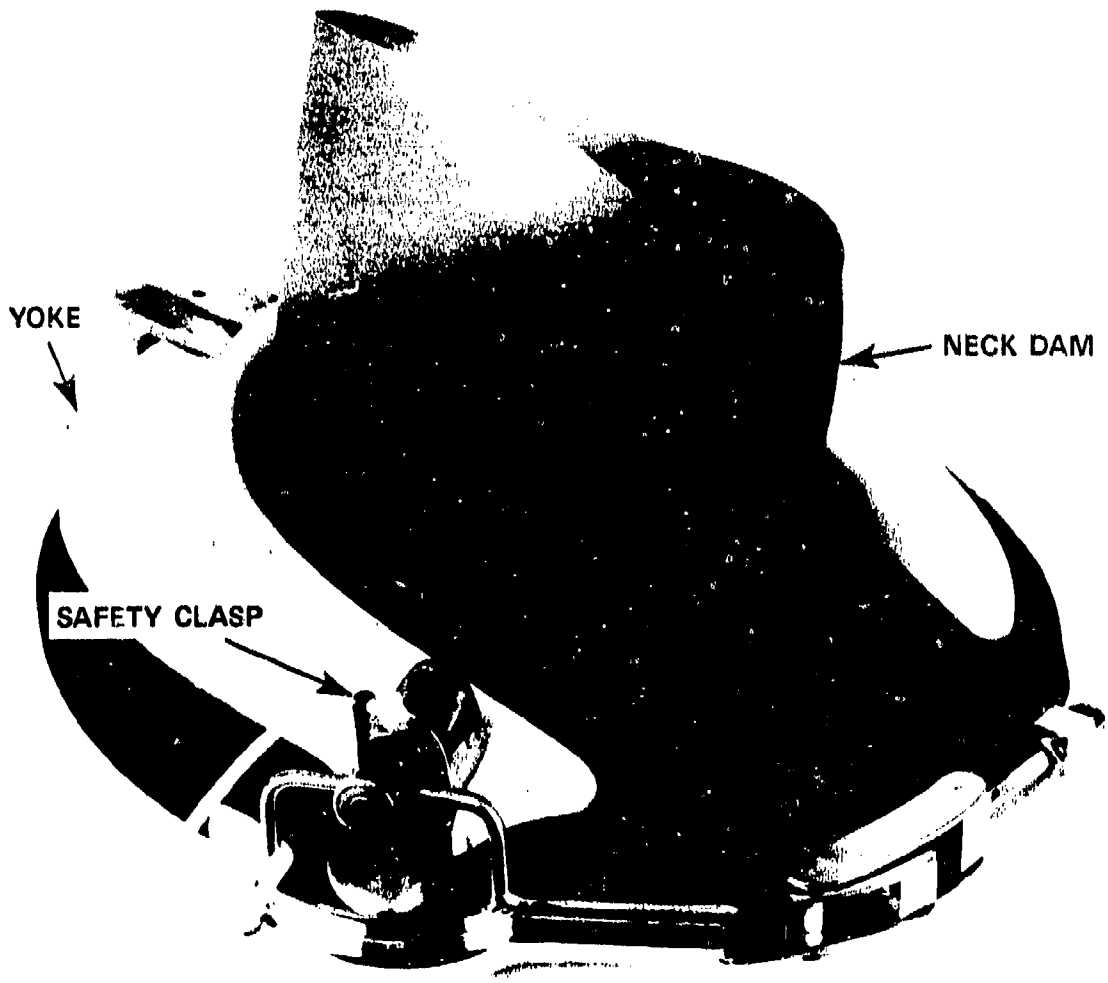

FIGURE 4. NECK DAM-YOKE WITH DRILLED SAFETY HOLE

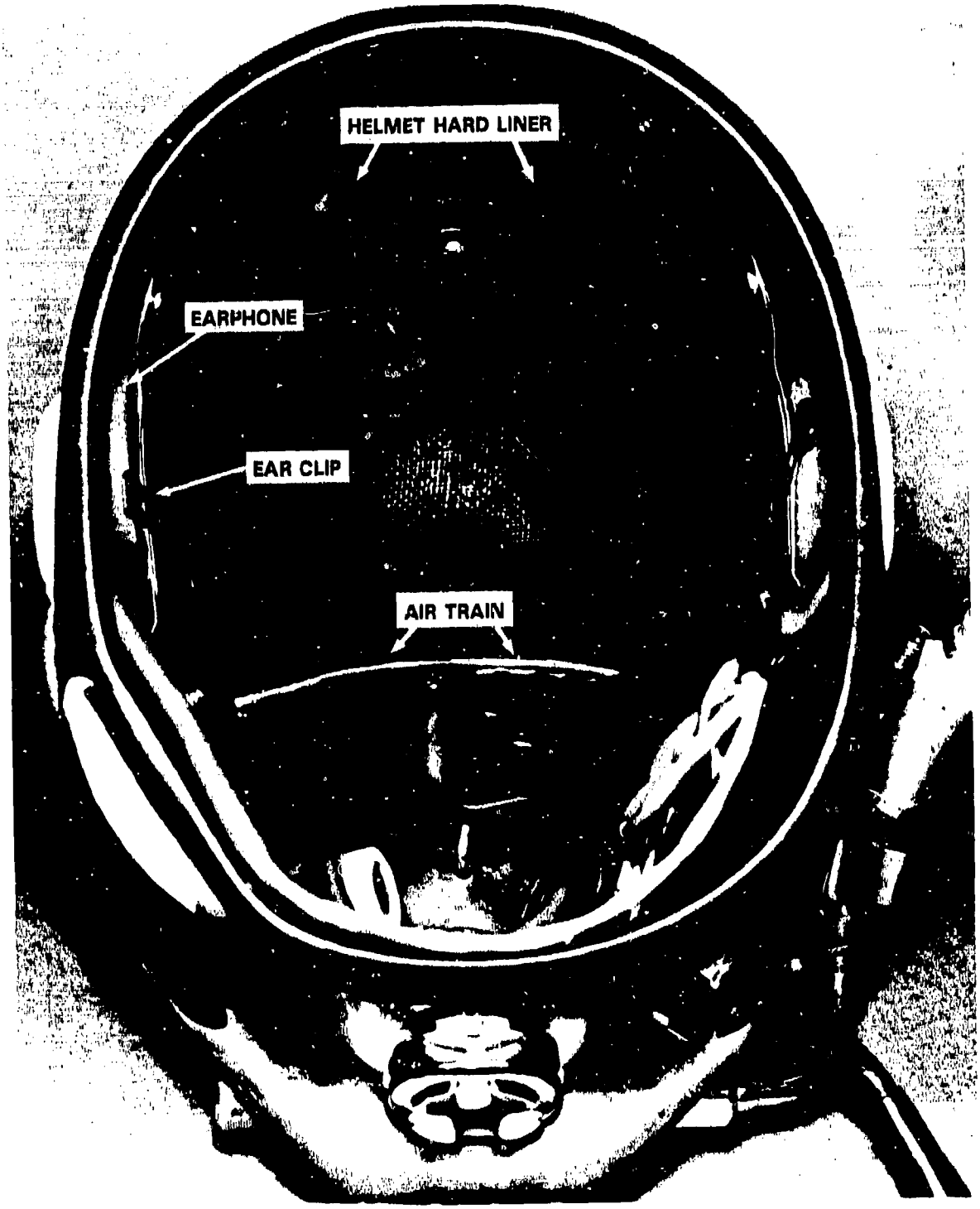

FIGURE 5. INTERIOR OF SL 17B HELMET

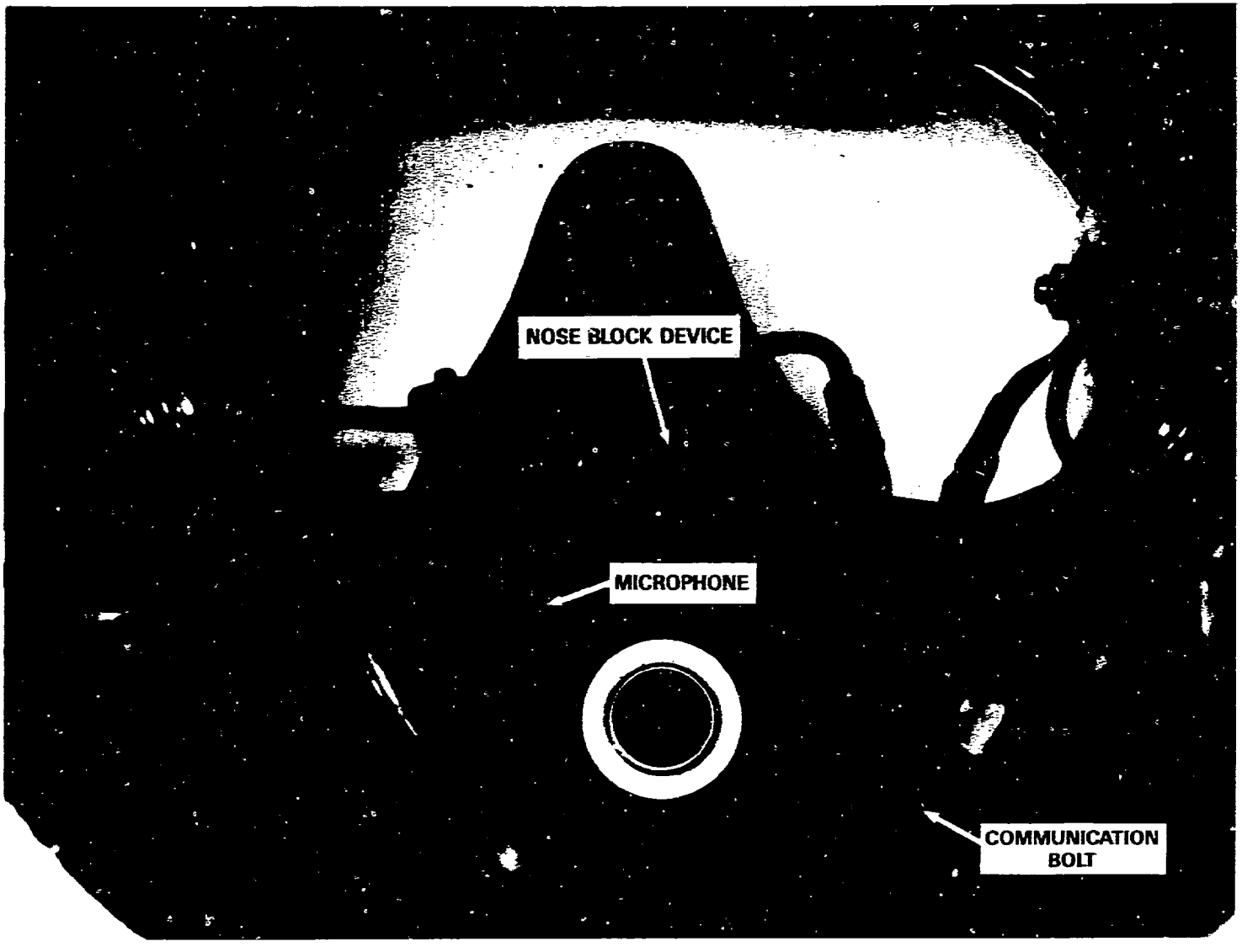

FIGURE 6. COMMUNICATION BOLT LOCATION AND NOSE BLOCK DEVICE

Tools Required: A slotted screw driver, pliers, and an adjustable crescent wrench appear to be the only tools required for basic maintenance on the SL 17B. Other tools (hammer, bent rod, a punch, angle wrench) are desirable for work on the demand regulator, and a scissors or knife are needed for trimming material for the head liner.

Nose Block Device: (Figure 6) Protruding into the oral-nasal mask is a rigid pre-formed metal rod in the shape of a "V" covered with rubber. This device is used as a platform for sealing the diver's nose when attempting to equalize pressure in one's middle ears. It can be pulled in and out by the diver, has about 2.5 cm of travel fore and aft, is 4 cm wide at the V, and is operated by grasping a 1.3 cm knurled knob just below the faceplate. This device is an essential effective feature to aid divers during surface-supplied diving. It could be improved by substituting a flexible material for the V portion of the device, therefore providing some adjustment for width and breadth of divers' noses.

Head Cushion: (Figures 7 and 8) The cushion is an important component in the degree of comfort experienced by the SL 17B diver. Attached to the helmet shell by 4 snaps, the cushion provides insulation against shock, temperature and sound. Properly fitted, the cushion takes up the excess space inside the helmet, so that the helmet moves as the diver's head moves. The head cushion was well made, exhibiting good sewing and pockets for adjusting the amount and location of the foam padding inserts. Different sized heads will require that adjustments be made in the head cushion configuration. The velcro chin strap eliminates metal objects and/or hard fasteners from around the face and is a good concept.

Neck Dam-Yoke: (Figure 4) The neck dam-yoke consists of a foam neoprene neck dam attached to a metal neck clamp. This is in turn fastened to a fiberglass yoke which fits around the diver's neck and rests on his shoulders. A rubber seal (o-ring) around the bottom of the helmet (Figure 1) provides a mating surface for the rubber neck dam, which is mechanically compressed by the use of the metal clamp (Figure 4). The yoke is large enough to fit around even a 46 cm diver's neck, and the neck dam is designed to be cut to size to form a snug yet not constricting seal. One potential drawback with this system appears to be the sizing of the neck dam to fit several divers. Too large a neck dam will result in water entry into the hat; too small a neck dam will cause constriction around the neck. Changing neck dams to accommodate different divers would appear to be necessary, and therefore require time between dives.

An instruction manual (copyrighted 1977) accompanied the newer Superlite 17B helmet. The manual was printed on glossy 8 1/2 x 11" paper, was 55 pages long, and contained clear black and white photographs and schematics. The text was well-written, grammatically correct, and should be easily understandable by a high school graduate. Photographs were located near the explanatory text, labeled and numbered. Safety advisories were distributed

FIGURE 7. HEAD CUSHION (ANTERIOR VIEW)

FIGURE 8. HEAD CUSHION (LATERAL VIEW)

throughout the manual in appropriate sections. Schematics and parts lists of the entire SL 17A & SL 17B assemblies were included at the end of the manual. In the manual, however, the SL 17A (vice SL 17B) is used in all illustrations, and there are differences in the newer helmets which are not explained or mentioned in the text. This may present some confusion to a novice; however, experienced divers should be able to use the manual in preparing and operating the SL 17B in a safe manner.

Summary of Bench Evaluation

Several changes in the SL 17B design were evident between the older and newer helmets in this test. Lighter helmet weight and a rubber covering on the nose clearing device are definite improvements; the effects of other DSI changes were not readily apparent and would require more sophisticated testing for definitive conclusions (e.g. differences in machining of the exhaust port). Components of the SL 17B appeared sturdy and resistent to structural failure. Areas amenable to re-design include the emergency gas supply handle (coarser threading leading to fewer turns required), demand regulator adjustment knob (fewer turns required), capping of the communication bolts, use of malleable metal in the nose block device, and the neck dam-yoke (to allow rapid removal and fitting of neck dams).

MANNED EVALUATION

A side-by-side comparison of the Superlite 17B with the U.S. Navy MK 1 Mod S Diver's Mask was undertaken. The MK 1 Mod S mask is presently used in diving from a PTC, and the Superlite 17B is being considered as a replacement for this mask in certain scenarios.

Subjects

Seven U.S. Navy male divers and one Royal Navy male diver served as subjects. All subjects were in excellent health, and their relevant physical and experiential characteristics are shown in Table 1.

Apparatus

A MK 1 Mod S mask (Figure 9) was obtained from the NEDU diving locker and adjusted to ensure performance in accordance with reference (8). All divers wore U.S. Navy integrated divers vests (IDVs) with full weights and a "come-home" bottle. The divers wore either a 0.3 cm thick neoprene short wet suit or heavy athletic shirts with swim shorts. Footgear consisted of sneakers or neoprene booties. MK 12 surface-supplied diving system umbilicals consisting of air hose, pneumofathometer and communication cable were used to deliver breathing gas to both diving rigs. The breathing medium was compressed air (79% nitrogen, 21% oxygen) supplied by air banks. Bottlefield pressure of 1600 psig was reduced to 160 psig by a regulator console and delivered to both diving rigs.

Communication among topside personnel, MK 1 Mod S divers and SL 17B divers was accomplished using a Hydroproducts Hydrocomm UC 225 communicator. Both the MK 1 Mod S and the SL 17B rigs were equipped with a Naval Coastal Systems Center (NCSC) pre-amplified microphone. The MK 1 Mod S mask was

TABLE 1. Relevant Diver Characteristics

Subject	Height(cm)	Weight(kg)	Neck Circumference(cm)	Approximate Number of Previous Dives in: MK 1	SL 17
A	177.8	88.5	39.0	20	3
B	185.4	93.9	42.0	3	3
C	177.8	70.9	38.0	80	2
D	186.1	101.2	42.5	200	10
E	194.9	115.2	44.0	200	20
F	177.8	64.4	35.5	100	3
G	185.4	90.7	40.0	4	3
H	190.5	85.3	39.0	500	2
$\bar{X}$	184.5	88.8	40.0	138	6
SD	6.4	16.1	2.7	--	--

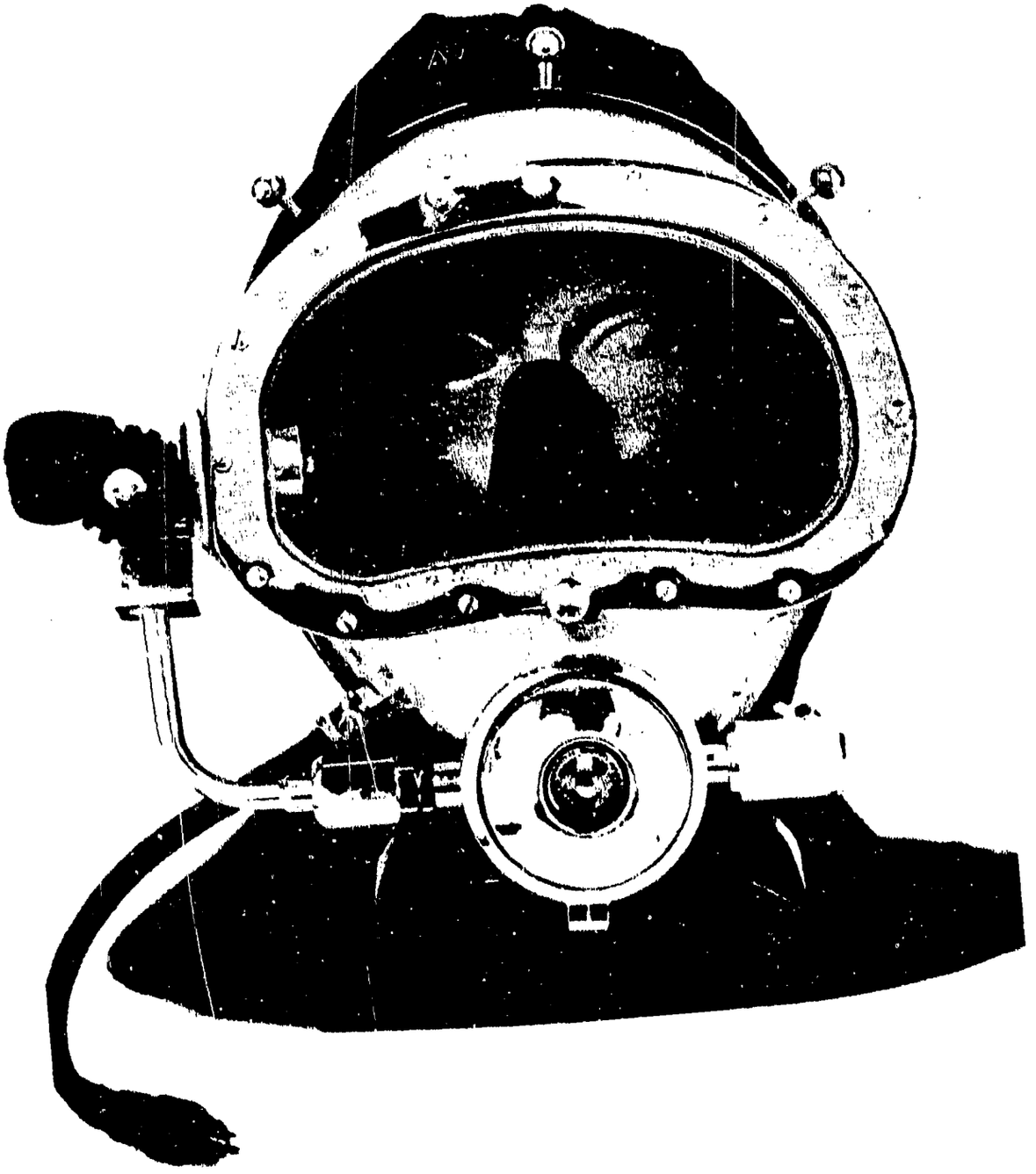

FIGURE 9. MK 1 MOD S MASK

fitted with a set of NCSC developed earphones, whereas the earphones supplied by DSI with the SL 17B were used with that helmet.

All diving was conducted in NEDU's indoor test pool filled with fresh water at a temperature of 84°F. Ambient air temperature ranged from 78-86°F. The pool's dimensions were 4.6m (W) x 9.1m (L) x 4.9m (D), with water depth approximately 4.6 m.

An underwater visual perimeter was employed to assess the diver's field of vision (Figure 10). This perimeter measured visual angles in 5° increments with radians in 30° increments for the entire 360° viewing field. Three fingered 0.6 cm (1/4") neoprene gloves and swim fins were used during various phases of the testing. A Collins Pedalmate Ergometer (Warren E. Collins, Inc., Braintree, MA) was placed in a locally constructed tilting frame and adapted for use underwater. Diver workload was varied using a Collins Pedalmate Controller on the surface which transmitted an electrical signal to the ergometer via an umbilical cable. A questionnaire (Appendix A) was constructed to query the divers on human factors aspects of both the MK 1 Mod S mask and the SL 17B diving helmet.

Procedure

The diver-subjects were briefed regarding the purposes and goals of this evaluation, the procedures for dressing and undressing the divers, the schedule of testing, and the proper completion of the post-dive questionnaire. An additional review was conducted on the proper set-up, take down and maintenance of the MK 1 Mod S diver's mask and the Superlite 17B helmet. Each subject received a familiarization dive in the SL 17B which lasted approximately 10-15 minutes.

The divers were then divided into four 2-man teams. Two teams undertook dives of two hours; one team dives of three hours, and one team dives of four hours. Each member of each team wore the MK 1 Mod S mask on one dive and the SL 17B on his second dive. Table 2 presents the schedule of dives accomplished during this evaluation. During each dive, both members of the team were in the water simultaneously, one diver wearing the MK 1 Mod S with his partner wearing the SL 17B. The older SL 17B was used during the first two days of testing, and was replaced by the new SL 17B on test days 3, 4, and 5.

Both divers were dressed in their respective diving gear simultaneously, and entered the water and received equipment and communication checks. Upon satisfactory completion of these checks, the divers proceeded to accomplish the tasks listed in Table 3. These tasks were designed to assist the divers in judging the comfort, fit and operation of the diving equipment. The diver's field of vision was measured using the perimeter and the method of limits with binocular vision. The standing diver's position was stabilized with the SL 17B or MK 1 Mod S centered both horizontally and vertically in the perimeter. The visual range was determined by the experimenter slowly moving a white pointer along the outside edge of the 180° arc of the perimeter. To simulate work, divers pedalled six minutes at 60 rpm against a 100-watt resistance and then rested for four minutes. Work/rest cycles were conducted in each of three attitudes: 45° head up, prone, and 45° head down. During

FIGURE 10. UNDERWATER VISUAL PERIMETER

TABLE 2. Order of Dives For Superlite 17B Human Factors Test

DIVE DAY	DIVE DURATIONS
1	15 min - All Teams
2	2 hrs (Team 1); 2 hrs (Team 3); 3 hrs (Team 4)
3	2 hrs (Team 3); 4 hrs (Team 2)
4	2 hrs (Team 1); 3 hrs (Team 4)
5	4 hrs (Team 2)

TABLE 3. Tasks Accomplished During Each Test Dive

Superlite 17B	MK 1 Mod S
Record dress and hat time	Record dress and hat time
In-water checks; comm checks	In-water checks; comm checks
Go through Emergency Procedures	Go through Emergency Procedures
Fall forward, backward, to either side	Fall forward, backward, to either side
Visual Field Test	Bicycle Ergometer 45°↑, prone, 45°↓, (100 watts)
Bicycle Ergometer 45°↑, prone, 45°↓, (100 watts)	Visual Field Test
Gloved and barehanded operation of valves	Standby
Standby	Gloved and barehanded operation of valves
Swim 20 laps	Standby
Standby	Swim 20 laps
Walk 20 laps	Standby
Standby	Walk 20 laps
Noise Assessment	Noise Assessment
Puzzle Project	Puzzle Project
Doff and Don	Standby to assist Superlite 17B Diver
Standby to assist MK 1 Mod S Diver	Doff and Don
SURFACE	SURFACE
COMPLETE QUESTIONNAIRE	COMPLETE QUESTIONNAIRE

each bicycle work phase, the diver rated the breathing resistance of the SL 17B or MK 1 Mod S during inhalation and during exhalation. Subjective noise assessment was also reported by all divers. Toward the latter portions of the three and four hour dives, both dive team members played chess or checkers while seated at an underwater table, or attempted to complete a complex pipe puzzle using nuts, bolts and wrenches. At the end of each dive, the divers surfaced, were undressed, and filled out the questionnaire.

Results

All dives were carried out as scheduled. The new SL 17B was received from DSI with a broken communication cable; this required replacement at the start of the test. Routine maintenance was conducted on each diving rig daily in accordance with references (7) and (8). Minimal instruction was required to prepare the diver-subjects to fully maintain the SL 17B diving helmet. Special tools were not required during this week of testing to maintain the SL 17B. The average time to "hat" the full-dressed diver was approximately 180 seconds for both the MK 1 Mod S and SL 17B divers at the start of the week's testing, which dropped to 90 seconds at the conclusion of testing.

The visual fields for divers wearing the Superlite 17B and the MK 1 Mod S mask were assessed using the underwater visual perimeter. Average visual fields for both rigs were virtually identical. As can be seen from Figure 11 the divers wearing the MK 1 Mod S mask displayed a relatively consistent, yet insignificant, larger visual field than the SL 17B divers. The magnitude of the difference in visual fields (~1.7°) can be attributed to measurement error.

The Superlite 17B helmet received very favorable ratings overall from all divers on human factors aspects of the rig. The divers' ratings and responses are summarized in Table 4. One noticeable exception to the favorable ratings occurred in the area of oral-nasal fit, where the SL 17B was judged to be less than adequate. The need for varying sizes of the oral-nasal mask was evident, as the installed mask was too large for some divers with resultant inadequate sealing around the face. There were also several areas in which the differences between the Superlite 17B and MK 1 Mod S mask became apparent in the ratings. Breathing resistance of the SL 17B was rated "minimal" and in all body positions was superior (subjectively) in breathing resistance to the MK 1 Mod S. This disparity was most pronounced in the prone and 45° head down positions.

Further, communications between topside and the Superlite 17B diver were rated much better than communications between the MK 1 Mod S diver and topside. This was reflected in the divers' answers to questions #8 and #12 in Table 4. Divers' comments centered on lack of clarity of communication received from topside, due in part to noise escaping the MK 1 Mod S exhaust and out of the neck dam. The divers also noted that on the surface the umbilical tended to pull the MK 1 Mod S to one side, whereas at depth this tendency was noted for both rigs. Overall, the divers rated the performance of the Superlite 17B helmet superior to that of the MK 1 Mod S mask as seen in the answers to question #19, Table 4. Nevertheless, the MK 1 Mod S mask still received good ratings in all areas except communications.

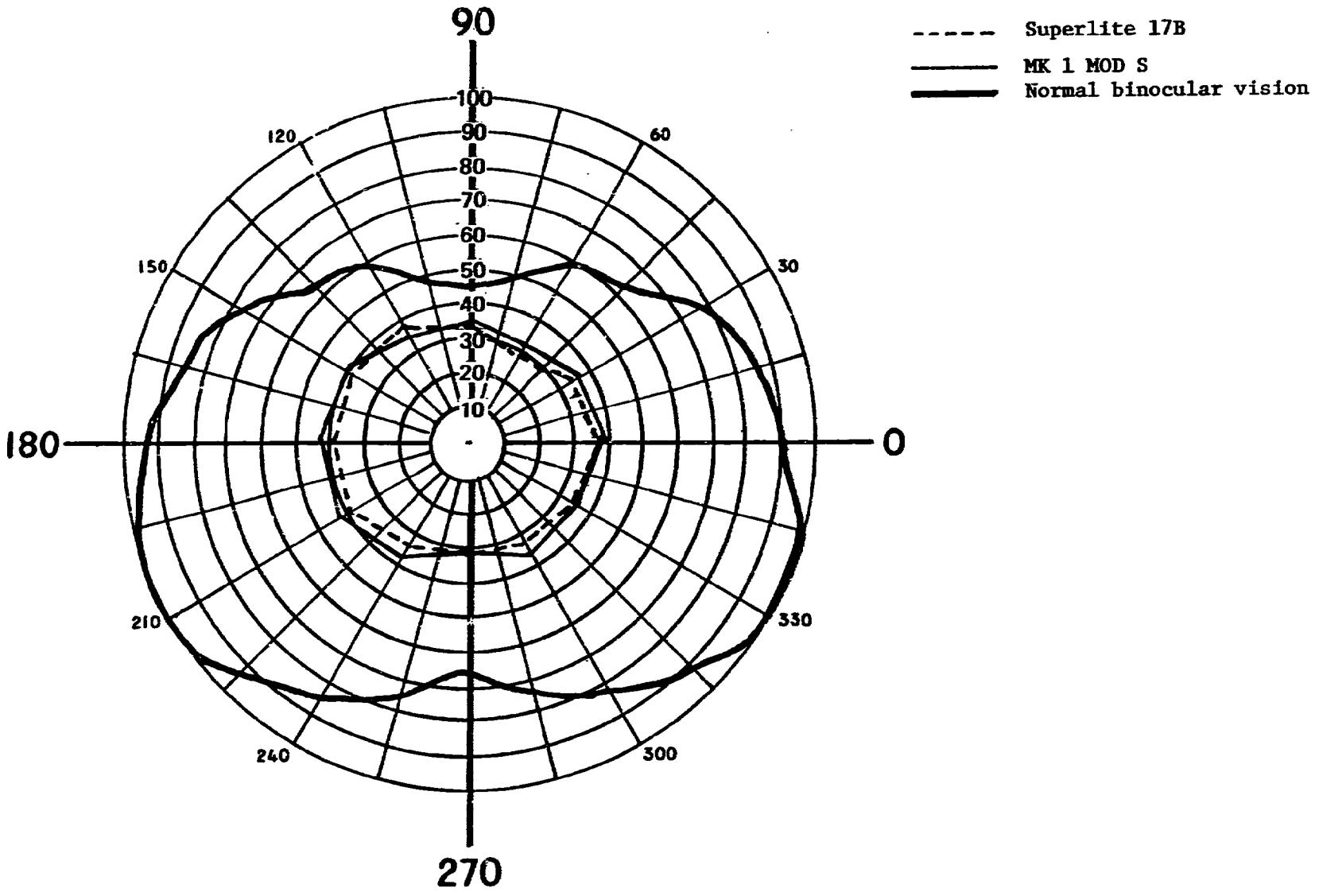

Figure 11. Diver Visual Fields in the SL 17B and MK 1 Mod S.

TABLE 4. Mean diver ratings (n=8 for each rig) on human factors aspects of the SL 17B and MK 1 Mod S; numbers in parenthesis are standard deviations.

Key For Questions 1 - 8:

1	2	3	4	5	6
extremely poor	poor	not quite adequate	adequate	very good	excellent

			SL 17B	MK 1 Mod S
1.	How do you rate the ease with which you were able to don the rig you have just worn?		4.9(.4)	5.1(.4)
2.	How do you rate the fasteners, fittings and valves on the rig?		4.8(.7)	4.8(.7)
3.	How do you rate the <u>fit</u> of:	Skull cap	4.8(.7)	----
		Oral-nasal	3.6(1.3)	4.0(.6)
		Shell/spider	4.7(.5)	4.2(1.2)
	<u>comfort of</u>:	Skull cap	4.6(.9)	----
		Oral-nasal	4.7(.5)	4.2(.5)
		Shell/spider	4.8(.8)	4.0(.9)
4.	How would you rate rig (diver's) visibility?		4.9(1.0)	4.1(1.0)
5.	How do you rate the rig you tested for freedom of moving about the topside area or topside work before entering the water?		4.8(.7)	5.0(.5)
6.	How do you rate the locations of the emergency valve on the rig you have worn?		5.1(.6)	5.2(.7)
7.	How do you rate the ease of operation of the valve(s) on the rig you have worn?		5.2(.5)	5.2(.5)
8.	How would you rate the communication system of the rig?		5.5(.5)	3.2(.9)
9.	Was the rig comfortable during the dive?		OK→Comfortable	OK→Comfortable
10.	Did faceplate fogging occur?		5 YES;3 NO	6 YES;2 NO
11.	During your dives did water enter the rig at any time?		8 YES	7 YES;1 NO
12.	When using the communication system, were you understood clearly and were you able to understand clearly when others talked to you?		8 YES	6 YES;2 NO

Key For Questions 13-16:

1 Heavy
2 Moderate
3 Tolerable
4 Minimal

		SL 17B	MK 1 Mod S
How would you rate the breathing resistance of the rig in the:			
13. Upright position	during inhalation:	3.9(.4)	3.7(.5)
	during exhalation:	3.9(.4)	3.7(.5)
14. 45° head up position	during inhalation:	3.9(.4)	3.5(.8)
	during exhalation:	3.9(.4)	3.2(.9)
15. Prone position	during inhalation:	3.9(.4)	3.2(.7)
	during exhalation:	3.8(.5)	3.1(.8)
16. 45° head down position	during inhalation:	3.6(.7)	2.9(1.1)
	during exhalation:	3.8(.7)	2.9(.6)
17. Did you have any difficulty swimming?		2 YES;5 NO	1 YES;7 NO
18. Did you have any difficulty walking?		8 NO	8 NO
19. In general, how would you rate the:		4.5(.5)(good/excel)	3.8(.7)(good)
20. In general, how was the rig balanced for comfort?			
	on the surface:	4.2(.5)(good)	3.8(.7)(good)
	at depth:	4.1(1.0)(good)	3.5(.5)(fair/good)
21. Did the neck dam fit properly? (SL 17B)		4 YES;4 NO	----
22. Did the neck dam leak? (SL 17B)		5 YES;3 NO	----
23. Did the umbilical tend to pull the rig to one side?			
	on the surface:	1 YES;7 NO	3 YES;5 NO
	at depth:	5 YES;3 NO	5 YES;2 NO
24. Did you use the nose-clearing device?		7 YES;1 NO	6 YES;2 NO
If YES, how well did it work?		4.0(.8)(good)	3.8(.4)(good)

SUPERLITE ONLY questions:

Did the helmet liner fit snugly?		7 YES;1 NO
Was the helmet liner comfortable?		
	on the surface:	8 YES
	at depth:	8 YES
Did the helmet liner place your face snugly into the oral-nasal mask?		6 YES;2 NO

The neck dam fit on the SL 17 is an important factor in keeping the diver dry and comfortable. During this test series the divers reported on several occasions that the neck dam did not fit properly (question #2) and leaked (question #22). It is of interest that this occurred despite the test crew possessing three sizes of neck dams and the choice being the diver's.

Whether diving the SL 17B or the MK 1 Mod S mask, divers reported that the umbilical tended to pull the diver's rig to the side. An effective strain relief is required when using either rig. All controls on the SL 17B were easily reached and operated by a gloved hand underwater. Faceplate fogging of the SL 17B was reported by 5 of 8 divers, and occurred during exercise on the bicycle ergometer. Fogging was easily cleared by turning the main gas supply handle, which supplied a steady flow of gas through the air train and into the helmet interior.

A post-test debrief was conducted with all divers. Points emphasized by the divers included the necessity of having different sizes of oral-nasal and neck dams readily available at the dive station, and the absence of a requirement for the locally installed locking pin. They believed that the use of the SL 17B in a Personnel Transfer Capsule is feasible and should not present any problems in deployment. The head cushion must be properly fitted so as to secure the diver's head and face in position inside the helmet.

Discussion

In this manned portion of the evaluation, several areas of concern were noted in the use of the SL 17B. First, it is essential that a snug fitting neck dam be used to prevent water entry into the helmet, and discomfort to the diver. In the course of the approximately 23 hours of manned SL 17B testing, three different sized neck dams were interchanged in an effort to provide a good fit for the seven divers. Only partial success was achieved. Ideally, each diver should possess a custom fitted neck dam. A new neck dam was supplied by DSI during the course of testing. Uncut, it was still too large to provide a snug fit for several divers. The manufacturing of the neck dam needs to be addressed to ensure adequate smaller neck sizing. Second, the oral-nasal mask was too large for most of our divers to achieve a snug and comfortable seal. Similar problems were reported by Canada's DCIEM, which found that substitution of an intermediate sized oral-nasal mask was satisfactory for most divers [reference (3)]. Further, DCIEM recommended that three sizes of oral-nasal masks be provided to cater to a wide range of facial characteristics. This is a sound suggestion. Third, proper packing of the head cushion is necessary to help maintain a proper oral-nasal seal and optimum comfort in the SL 17B. Individually issued, custom-packed head cushions were used in this study and found most satisfactory.

Regarding the balance of the helmet, the divers rated it as good. Brief comparisons of the older SL 17B and the newer SL 17B by two divers found that the newer SL 17B was preferred by both divers in the area of balance. Despite dives of up to four hours in the SL 17B, no complaints regarding helmet balance were noted. These findings contrast with those reported by DCIEM. The Canadians found that helmet balance was poor and "led to an upward moment...which had a tendency to displace the oral-nasal and exaggerate any poor fitting of the helmet liner" [reference (3)]. DCIEM corrected for this

tendency by placing ~1.7 lbs of lead ballast inside the helmet immediately below the faceplate. It is uncertain as to the comparability of the weighting of the SL 17B in DCIEM's study and the SL 17Bs in the present evaluation. DCIEM also reported that their cold water neck dam contributed to the upward moment of the helmet. Regardless, helmet balance was not found to be a problem during this study.

In dives of up to four hours, divers reported no undue discomfort from wearing the Superlite 17B. With practice, the helmet can be donned safely by the diver alone. These results suggest that the Superlite 17B may be suitable for use in a PTC.

CONCLUSIONS

The Superlite 17B diving helmet was evaluated from a manned and unmanned human factors engineering perspective. Within the scope of this evaluation, no major discrepancies were noted in the areas of diver comfort, safety and operation. Care, however, must be exercised in the fitting of neck dams, oral-nasal masks and head cushions to ensure safe and comfortable use of the helmet. Several areas of concern were noted in the construction of the helmet, which appear amenable to modification by the manufacturer. Recommended solutions to these concerns include a more easily shaped nose-clearing device, protectively capped communication bolts, manufacturing of smaller neck-dams, supply of smaller oral-nasal masks, and reconfiguration of the emergency gas supply and the demand regulator adjustment to require fewer turns from full open to full shut. A non-essential but desirable reconfiguration of the neck-dam/yoke assembly to provide quicker swapping of neck-dams is recommended.

REFERENCES

1. Middleton, James R. Evaluation of the Diving Systems International Superlite 17B Helmet. Navy Experimental Diving Unit Report No. 9-79, November, 1979.

2. Schwartz, H.J.C. Manned Testing of the Superlite 17B Diving Helmet Compared With the MK 1 Mod S Diver's Mask. Navy Experimental Diving Unit Report No. 4-83, June, 1983.

3. Hewitt, J.T. and Lauckner, G.R. Carbon Dioxide Poisoning Causes and Elimination in SL 17B Diving Helmet. Defense and Civil Institute of Environmental Medicine Technical Memorandum of 2 June 1982.

4. Hewitt, J.T. and Lauckner, G.R. Active Gas Heating SL 17B Helmet. Defense and Civil Institute of Environmental Medicine Technical Memorandum of 8 May 1982.

5. Mitchell, R.P. and Lauckner, G.R. Selection of DSI SL 17B Diving Helmet For Use in Surface-Supplied Diving. Defense and Civil Institute of Environmental Medicine Technical Memorandum of 1 May 1982.

6. Curley, M.D. and Schwartz, H.J.C. A Comparative Human Factors Evaluation of the Superlite 17B Dry Helmet and the MK 1 Mod S Diver's Mask. Navy Experimental Diving Unit Test Plan No: 84-16, April 1984.

7. Kirby, Bob and Morgan, Bev. Superlite 17 Diver's Helmet. Diving System International, July, 1977.

8. U.S. Navy Diving Manual, Volume 1, Change 2, 1978. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

APPENDIX A

SL 17B MK 1 MOD S

(Circle One)

NAME _____ DATE _____

Ht _____ Wt _____ Length of Dive _____

How many previous dives in this rig? _____

---

1. Extremely poor
2. Poor
3. Not quite adequate
4. Adequate
5. Very good
6. Excellent

Select the number indicating your response to the following questions:

1. How do you rate the ease with which you were able to don the rig you have just worn? _____

Comments or suggestions: _____

2. How do you rate the fasteners, fittings and valves provided on the rig? ___

Comments or suggestions: _____

3. How do you rate the fit of: comfort of:

Skull Cap	_____	_____
Oral-Nasal	_____	_____
Shell/Spider	_____	_____

Comments or suggestions: _____

4. How would you rate:

Rig (Diver's) Visibility?_____

Comments or suggestions:

5. How do you rate the rig you tested for freedom of moving about the topside area or topside work before entering the water?_____

Comments or suggestions:

6. How do you rate the locations of the emergency valve on the rig you have worn?_____

Comments or suggestions:

7. How do you rate the ease of operation of the valve(s) on the rig you have worn?_____

Comments or suggestions:

8. How would you rate the communication system of the rig? _____

Comments or suggestions:

Circle Appropriate Answer

9. Was the rig comfortable during the dive(s)?

Very Uncomfortable	Uncomfortable	OK	Comfortable	Very Comfortable
(1)	(2)	(3)	(4)	(5)

If uncomfortable, explain:_____

_____

_____

10. Did faceplate fogging occur?

YES	NO
(1)	(2)

If so, when?_____ And did it prevent you from completing your assigned task?_____

_____

11. During your dives did water enter the rig at any time?

YES	NO
(1)	(2)

If so, describe (how much water, what caused it, did you have to surface, did it flood out, were you able to clear it):_____

_____

_____

12. When using the communication system, were you understood clearly and were you able to understand clearly when others talked to you?

YES	NO
(1)	(2)

Explain:_____

_____

_____

_____

Select the most appropriate answer below for the following questions:

1. Heavy
2. Moderate
3. Tolerable
4. Minimal

13. How would you rate the breathing resistance of the rig in the up-right position? During Inhalation_____ During Exhalation_____

Comments or suggestions:

14. How would you rate the rig's breathing resistance in the 45° head-up position? During Inhalation_____ During Exhalation_____

Comments or suggestions:

15. How would you rate the rig's breathing resistance in the prone position? During Inhalation_____ During Exhalation_____

Comments or suggestions:

16. How would you rate the rig's breathing resistance in the 45° head-down position? During Inhalation_____ During Exhalation_____

Comments or suggestions:

17. Did you have any difficulty swimming? YES___ NO___

If YES, please explain:_____

_____

_____

_____

18. Did you have any difficulty walking? YES___ NO___

If YES, please explain:_____

_____

_____

_____

19. What part of the pre-dive check list would be the easiest to overlook?

_____

_____

_____

_____

20. In general, how would you rate the performance of the rig?

Unsatisfactory	Poor	Fair	Good	Excellent
(1)	(2)	(3)	(4)	(5)

21. In general, how was the rig balanced for comfort?

a. On the surface?

Unsatisfactory	Poor	Fair	Good	Excellent
(1)	(2)	(3)	(4)	(5)

b. At depth? (In all positions)

Unsatisfactory	Poor	Fair	Good	Excellent
(1)	(2)	(3)	(4)	(5)

Additional comments on balance:_____

_____

_____

_____

22. Did the neck dam fit properly?

YES	NO
(1)	(2)

23. Did the neck dam leak?

YES	NO
(1)	(2)

General comments on the neck dam:

24. What about the balance of the umbilical against the rig, did it tend to pull the rig to one side?

a. On the surface?

YES	NO
(1)	(2)

b. At depth?

YES	NO
(1)	(2)

25. Did you use the nose clearing device?

YES	NO
(1)	(2)

If yes, how well did it work?

Unsatisfactory	Poor	Fair	Good	Excellent
(1)	(2)	(3)	(4)	(5)

SUPERLITE ONLY

1. Did the helmet liner fit snugly?

YES	NO
(1)	(2)

SUPERLITE ONLY
(Continued)

2. Was the helmet liner comfortable?

a. On the surface?

YES (1) NO (2)

b. At depth?

YES (1) NO (2)

3. Did the helmet liner place your face snugly into the oral-nasal mask?

YES (1) NO (2)

4. What pieces/parts of the SL 17B appear to lack durability or sturdiness if it was subjected to Fleet use?